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BUCLAP2

A COMPUTER PROGRAM FOR INSTABILITY ANALYSIS OF LAMINATED LONG PLATES SUBJECTED TO COMBINED INPLANE LOADS

PROGRAM DESCRIPTION DOCUMENT

by

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16. Abstract

This program description document describes the program structure and the design details of a CDC 6600 FORTRAN IV digital computer program, BUCLAP2, which uses minimum energy principles to do an elastic stability analysis of curved and flat laminated rectangular long plates subjected to combined inplane normal and shear loads.

Given the geometry, the material properties, and selected boundary conditions for the plate element, the program calculates the minimum buckling load for various wave lengths. The two parallel ends of the long plate must be simply supported and arbitrary elastic boundary conditions may be imposed along either one or both external longitudinal sides.

The theoretical basis of BUCLAP2 and correlations of calculated results with known solutions are presented in another document. Also the guide to program use is in a separate document.

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Loading, shear and biaxial
Structure

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CONTENTS

1.0 PROGRAM DESCRIPTION

The program BUCLAP2 uses minimum energy principles to do an elastic stability analysis of a curved or flat, laminated, rectangular long plate subjected to combined inplane normal and shear loads.

The structure of the program can be understood from the fundamental problem which is being solved. The fundamental problem is:

$$|S_\sigma| = 0 \tag{1}$$

where S_σ is the stiffness matrix of the plate under consideration with the appropriate boundary conditions applied for a given load, σ. This problem is classified as a general nonlinear eigenvalue problem. The elements of S_σ are transcendental functions of the external loading, σ, and the axial half-wave length of buckling (a/m).

For any chosen number of axial half-waves (a/m), the lowest level of external loading at which equation 1 is satisfied is the buckling load of the structure. This load is determined by an iteration procedure. A series of (a/m) values are investigated and the lowest of all buckling loads then gives the critical load of the structure

The above-mentioned iteration procedure may be described as follows: For a given (a/m) value there is an associated interval, $\sigma_\ell \leqslant \sigma \leqslant \sigma_u$, of interest (this interval is either calculated or specified by input). A modified bisection search technique is applied to the interval. So for the first iteration, σ equals $\sigma_\ell + f(\sigma_u - \sigma_\ell)$, $(0 < f < 1)$. For this load, σ, the stiffness matrix for the plate is calculated using equation A.53 of reference 1. The elemental matrix is merged into S_σ by applying the boundary conditions and stiffnesses of the edges of the plate.

The resulting S_σ matrix is complex Hermitian. The choice between subinterval $[\sigma_\ell, \sigma]$ and $[\sigma, \sigma_u]$ that is of further interest is dictated by whether the determinant is positive definite, or not, at σ. If positive, the right subinterval is chosen as the new interval; if not, the left. The objective is to reduce the length of the interval being investigated to a suitable tolerance. As the quantity σ (which is being sought) is changed, S_σ changes in a complex manner. This characteristic affects the structure of the program profoundly.

1.1 PROGRAM FUNCTION

The program consists of three primary overlays with one primary having three secondaries.

Overlay	Function
0.0	Monitors basic control
1.0	Inputs and processes data
2.0	Monitors control through load calculation
2.1	Calculates wave numbers for minimum search
2.2	Calculates upper bound loads for list of wave numbers
2.3	Obtains minimum load of plate for list of wave numbers
4.0	Summarizes load calculation at minimum value

The process of producing the plate merged stiffness matrix S_σ is done in the routines DATIN, DC, MERGEC and STOREC. A discussion of this process follows. The plates may be visualized as consisting of two nodes, each node with four degrees of freedom, w, θ, v, u:

w - out-of-plane displacement

θ - rotation about plate sides

v - inplane displacement in lateral direction

u - inplane displacement in longitudinal direction

S_h - stiffness matrix of half-plate

S - stiffness matrix of "full plate"

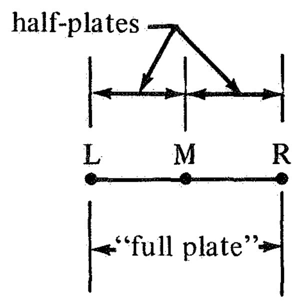
The merged stiffness matrix for a plate P is produced by generating the stiffness matrix for a half-plate P_h with width one-half of P. This matrix is used in producing both the left part and right part of P. The left part consists of the matrix for half-plate P_h and the boundary conditions and nodal stiffnesses at the left edge of P. The right part consists of the matrix for half-plate P_h and the boundary conditions and nodal stiffnesses of the right edge of P.

Discussion of Merge procedure follows:

Given X_d, X_f, then $S_h \cdot X_d = X_f$ or $S_h = X_f \cdot X_d^{-1}$

$$S_h = \begin{array}{cc} & \begin{array}{cccccccc} & \ell & & & & r & & \\ 1 & 2 & 3 & 4 & 1 & 2 & 3 & 4 \end{array} \\ \begin{array}{cc} & 1 \\ \ell & 2 \\ & 3 \\ & 4 \\ & 1 \\ r & 2 \\ & 3 \\ & 4 \end{array} & \left[\begin{array}{c:c} S_{\ell\ell} & S_{\ell r} \\ \hdashline S_{r\ell} & S_{rr} \end{array}\right] \end{array}$$

Freedom type	Component position
w	1
θ	2
v	3
u	4

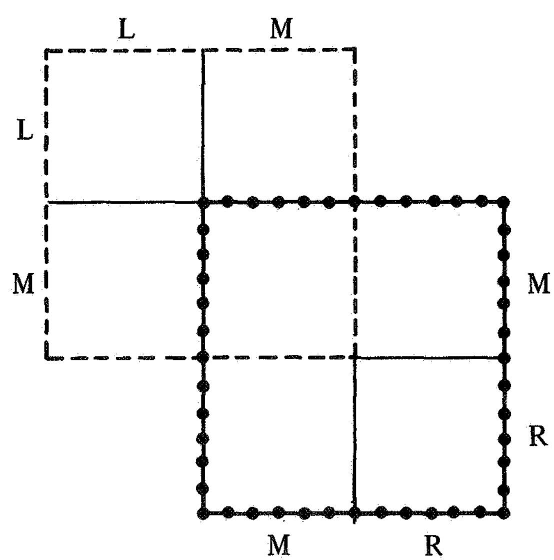


L - left boundary

M - middle

R - right boundary

S =



Merged Matrix Before Row Deletion

Both matrices (dashed and dotted) have the same members before deletion. The deletion of a freedom for a plate side is accomplished by deleting the row and column of the merged matrix corresponding to the side and freedom (i.e., if w = 0 for side L then column corresponding to L_1 is deleted and row L_1 is also deleted).

Merge Process

Step 1.—The initial identification list is modified by deleting those members for which the freedom has been constrained, i.e., let

$$v \text{ for } L = 0$$

and

$$w \text{ for } R = 0$$

then:

n = gross matrix size

Initial list

L	w	1
	θ	2
	v	3
	u	4
M	w	5
	θ	6
	v	7
	u	8
R	w	9
	θ	10
	v	11
	u	12

Final list

L	w	1
	θ	2
	u	3
M	w	4
	θ	5
	v	6
	u	7
R	θ	8
	v	9
	u	10

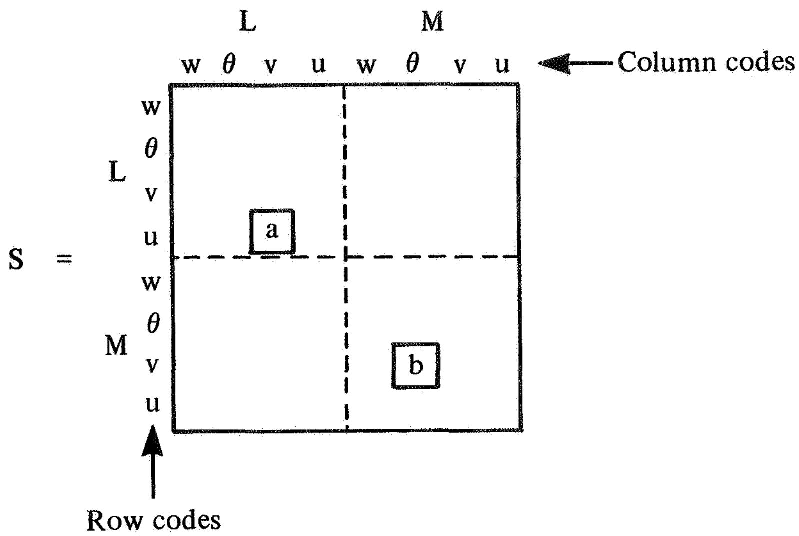
$n = 10$

Note: In the program, L, M, and R are specified by 1, 2, and 3, respectively. Also w, θ, v, and u are denoted by 1, 2, 3, and 4, respectively. The merge list is packed. The example from above would appear:

Row		
1	1	1
2	1	2
3	1	4
4	2	1
5	2	2
6	2	3
7	2	4
8	3	2
9	3	3
10	3	4

Step 2.—Given elemental matrix S

Merge S for left part (L, M) and right part (M, R)



a. Member's $\left\{\begin{array}{ll} \text{row code} & \text{L, u} \rightarrow k_r = 3 \\ \text{col code} & \text{L, v} \rightarrow k_c \text{ (does not exist)} \end{array}\right.$

Member will be deleted.

b. Member's $\left\{\begin{array}{ll} \text{row code} & \text{M, v} \rightarrow k_r = 6 \\ \text{col code} & \text{M, } \theta \rightarrow k_c = 8 \end{array}\right.$

Then

$$C(6, 8) = C(6, 8) + S(7, 6)$$

where

C = array containing merged matrix

Step 3.—The left edge spring constant is added to the L, L nodal component, and for the right edge the R, R is added to.

1.2 OVERLAY STRUCTURE

<table>
<tr><td colspan="5">Main overlay 0.0
Program name S0352A
Subroutines PRINTC
ERROR</td></tr>
<tr><td>Primary overlay 1.0</td><td colspan="3">Primary overlay 2.0</td><td>Primary overlay 4.0</td></tr>
<tr><td rowspan="3">Program name: DATIN

Subroutines: PAC
PRERD
NEXTC
UNPAC
PLTDEF
RDTBLE
TBPOINT
INFORM
STRMOV
PLACE
COMCHK</td><td colspan="3">Program name: SELECT</td><td rowspan="3">Program name:
STRAIN
Subroutines:
ASTAR
SIMEQ</td></tr>
<tr><td>Secondary overlay 2.1</td><td>Secondary overlay 2.2</td><td>Secondary overlay 2.3</td></tr>
<tr><td>Program name:
WAVFND</td><td>Program name:
GALUP
Subroutines:
ASTAR
REDUC3
EECM
SIMEQ</td><td>Program name:
LOADCL
Subroutines:
LOADCN
SORT
DC
MERGEC
STOREC
CHMDET
DBLERT
AROOT
PLATEC
PLTCLC
CALVET
RGENER
SOLVEC
PAC
DTC
CDTM
VIPDR
ZARK2
CXINV</td></tr>
</table>

1.3 BASIC PROGRAM FLOW

Figures 1 through 6 are a visual elaboration of the basic control flow of the program. The overall flow is indicated on the first figure, with elaboration of each part except GALUP and STRAIN on the following flow charts.

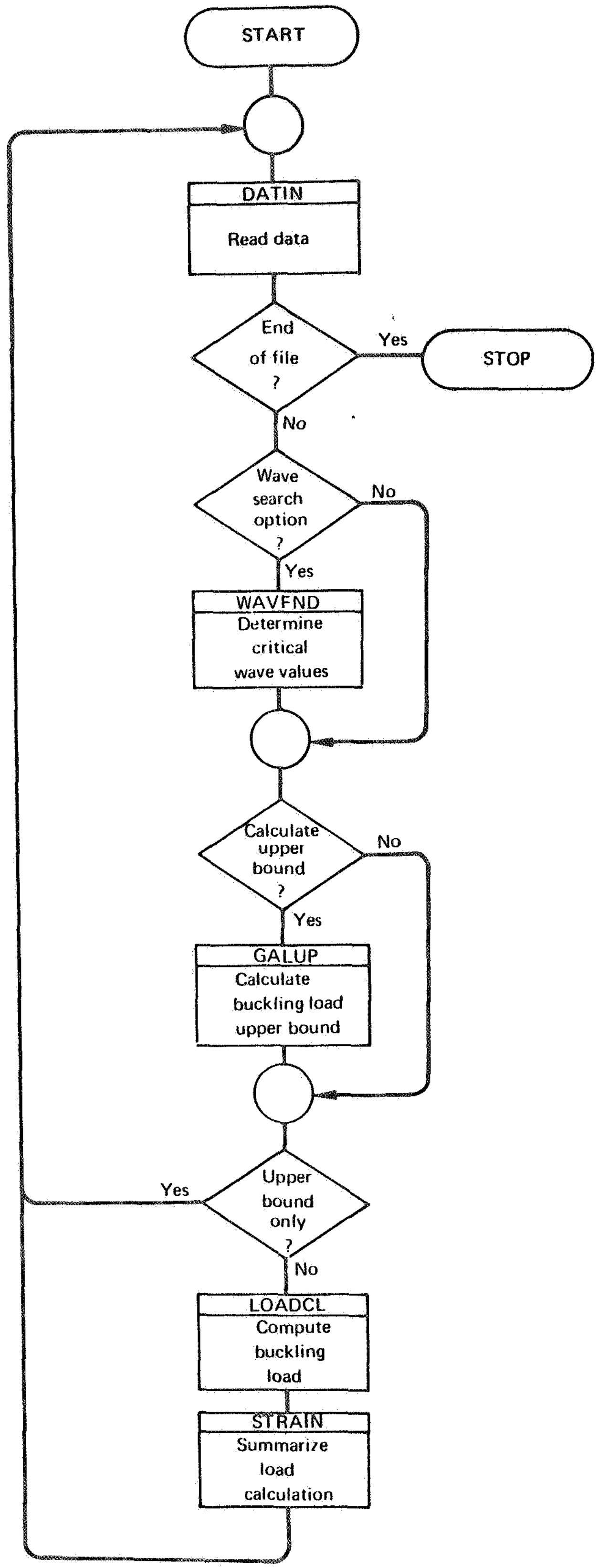


FIGURE 1.—OVERALL FLOW CHART

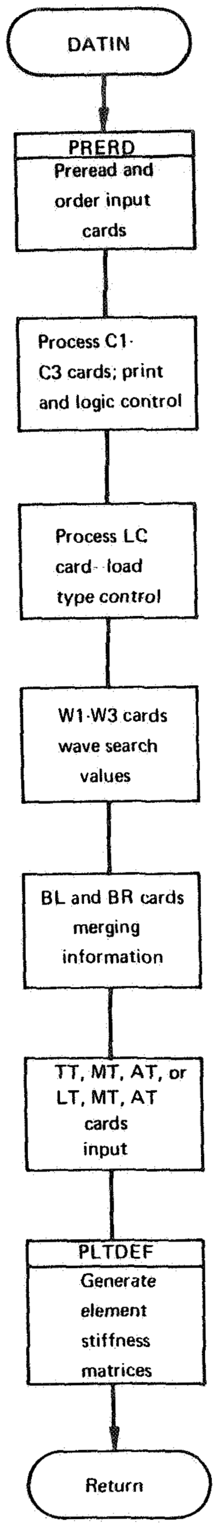


FIGURE 2.—FLOW CHART OF PRIMARY OVERLAY 1.0

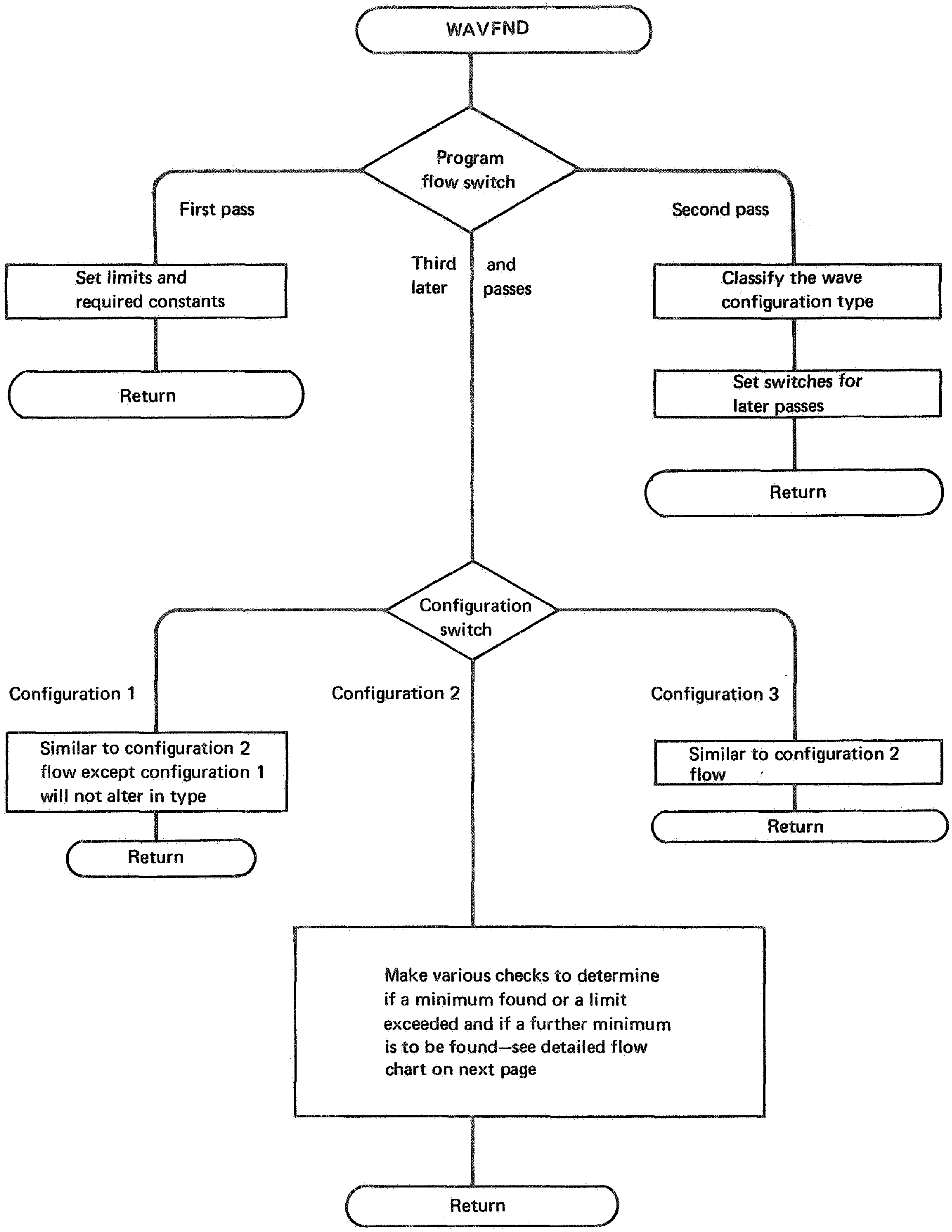


FIGURE 3.—FLOW CHART OF SECONDARY OVERLAY 2.1

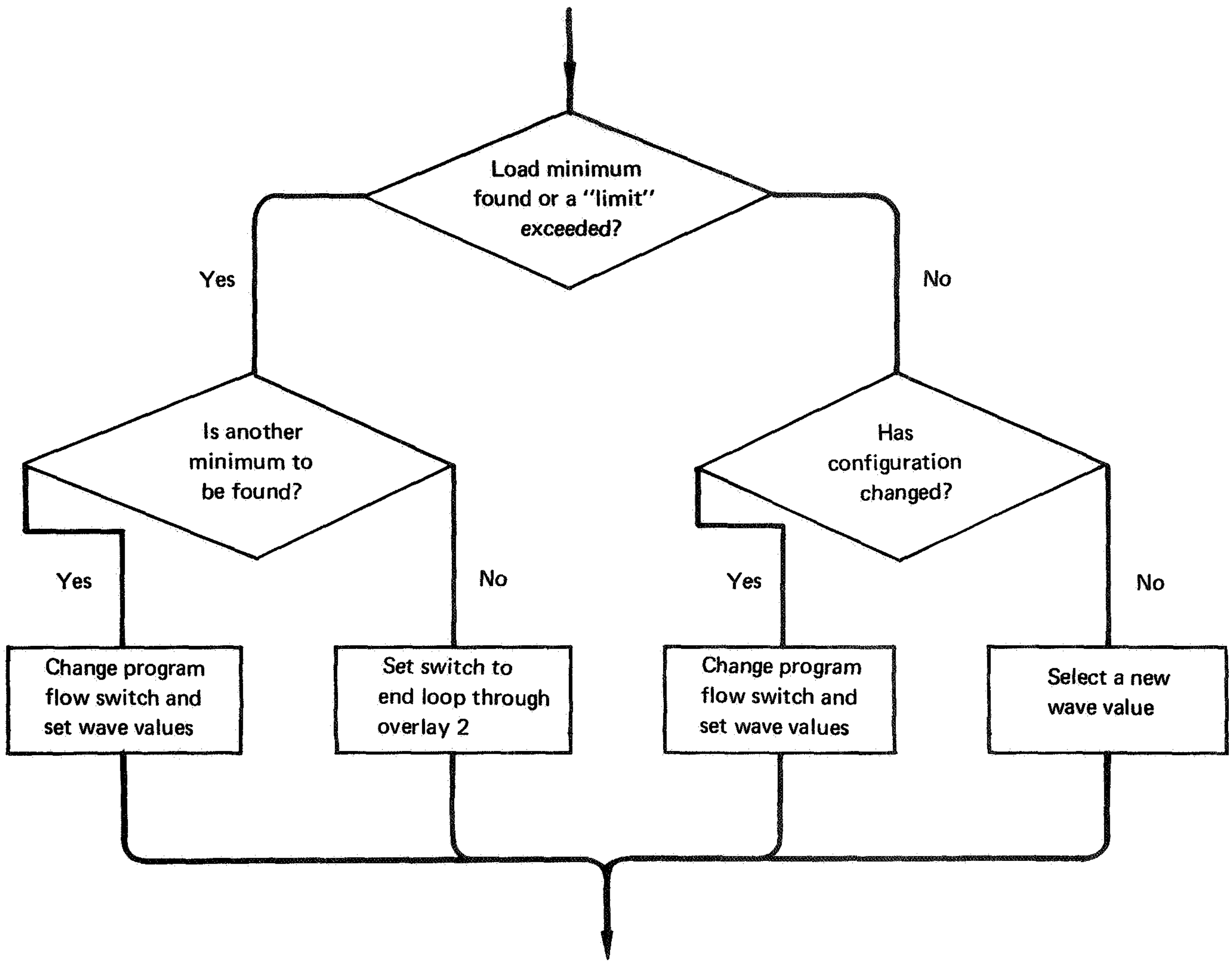


FIGURE 4.—DETAILED FLOW FOR CONFIGURATION 2 IN WAVFND

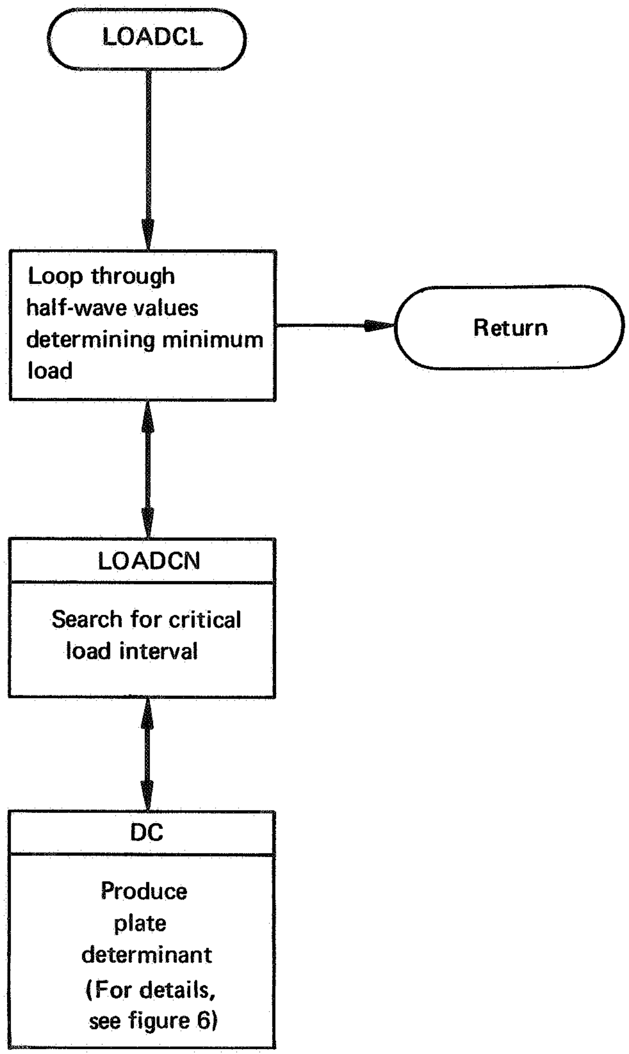


FIGURE 5.—FLOW CHART OF SECONDARY OVERLAY 2.3

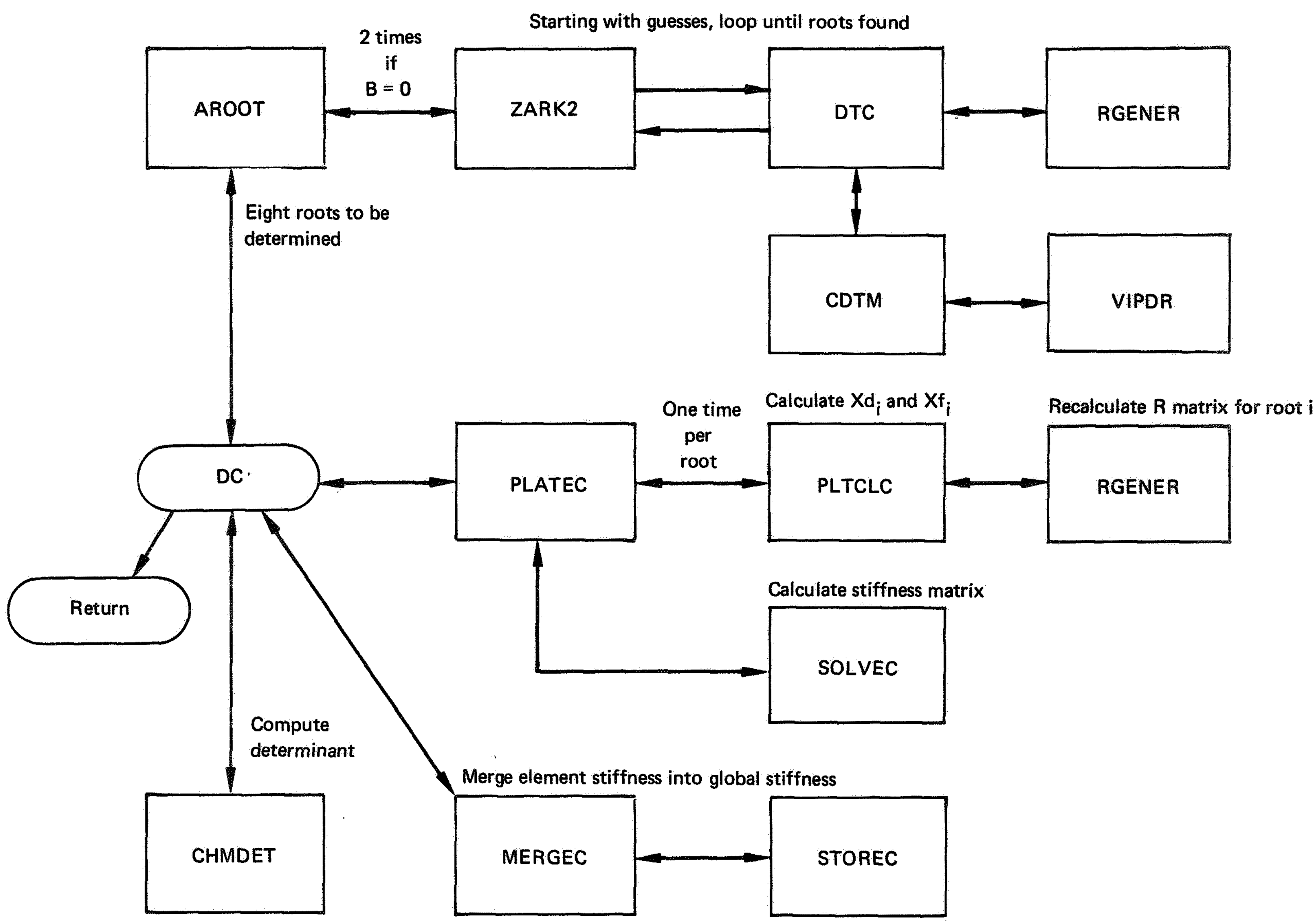


FIGURE 6.–DETAILED FLOW CHART OF DC

1.4 COMMON BLOCK DEFINITIONS

All common block variables are here defined. Any variables not in common are defined, where desirable, by comment cards in the subroutine.

Common block	Variable	Description
ABD	A	Extensional stiffness matrix
	B	Coupling stiffness matrix
	D	Bending stiffness matrix
	MATXB	B matrix switch = 0 flat plate has zero B matrix = 1 flat plate has nonzero B matrix or curved plate
ACON	ACON	A constant that is set in the DATIN subroutine according to the load option and is used in GALUP subroutine for the upper bound calculation
ANGCM	NOANG	Number of angles in the angle table (an input)
	ANGLE	Angles for fiber direction (angle table)
BOUND	SUP	Upper bound for critical load first as input or as calculated by Galerkin method; second, as end result of LOADCN iterations
	SLW	Lower bound for critical load first as input; second, as end result of LOADCN iterations
	UPBND	Upper bounds for critical loads as calculated in GALUP by the Galerkin method

Common block	Variable	Description
CNTROL	DONSWI	Donnell switch
	IPC	Array of intermediate switches
	JPC	Array of control switches
CONPNT	IPRNT1	Applied inplane loads check print switch
	IPRNT2	R matrix check print switch
	IPRNT3	X_d, X_f and stiffness matrix check print switch
	IPRNT4	Merged stiffness check print switch
	IPRNT5	Load search check print switch
CONTRL	DOUBLE	Double root detection switch
	NZERO	Nonzero determinant switch
	POSTVE	Positive definite determinant switch
CWAVAL	RMA	Current wave number being searched
DBTRAN	LRTRN	Return address for double root detection
DCARD	KTITL	Title for problem which is placed at top of each output page

Common block	Variable	Description
	IKARD	Array of last 78 characters on an input card
	IERFLG	Input error flag (or switch)--controls flow in program's input section
	ICRD	First two characters on an input card
	NPAGE	Page number for the output of a problem
DSTIFF	DSTIFF	Nodal stiffnesses for plate edges
ICK	IX	Count of number of determinant evaluations
INFO	WIDE	Width of flat plate; chord width of a curved plate
	XL1	First load value (input)
	XL2	Second load value (input)
	SWAVE	Half-wave length
	IPRLFT	Left boundary option (SS, CL, FR, blank)
	IPRRHT	Right boundary option (SS, CL, FR, blank)
	KEND	Pointer to VMIN's position
	VMIN	Local minimum buckling load
	IDISP	Left and right boundary conditions
LOADVL	AN11	Applied inplane load in the 11 direction

Common block	Variable	Description
	AN12	Applied inplane shear in the 12 plane
	AN22	Applied inplane load in the 22 direction
MERGE	NRWS	Number of rows in merged stiffness matrix
	NCLS	Number of columns in merged stiffness matrix
	MRLIST	List of merge information
NDIR	NDIR	Switch controlling direction of calculations in the WAVFND subroutine
NND	NND	Number of negatives on diagonal of merged stiffness matrix
OPTION	LDOPT	Load search option
	BNDLWR	Input lower bound for load search
	BNDUPR	Input upper bound for load search
	RIX	Constant NX load
	RIY	Constant NY load
	RIXY	Constant NXY load
	RXY	NX/NY ratio
	RXXY	NX/NXY ratio
	RYXY	NY/NXY ratio

Common block	Variable	Description
PLATE	IETYPE	Element type = 1 flat plate = 2 curved plate
	PLONG	Length of plate
	WIDTH	Plate half width
	RADIUS	Plate radius
PRECOM	KREAD	Switch signalling whether or not to read a card on initial entry to PRERD
	TCARD	Array of input card images
	IEOF	Switch indicating whether or not an EOF has been read
PROOTC	NR	Number of α roots to be obtained as a group
	NT	Total number of α roots obtained
	KXZ	Switch used in AROOT to indicate in B = 0 case if roots are from 2 x 2 (=1) or 1 x 1 (=0)
	KXT	Switch used in PLATEC to indicate in B = 0 case if columns are first four (=0) or last four (similar to KXZ (=1)
	KXY	Indicates if B = 0 and flat plate (=1) and if not (=0)
	PIX	Array containing α root type information
	P	Complex array containing α roots

Common block	Variable	Description
RC	R	Array containing stability equations matrix
RDCOM	CARD	Array containing ordered input cards
	KDNT	Total number of data cards
	KDNO	Counter for data card image to be processed
STRCM	NLAY	Number of layers
	THTA	Angle for fiber direction for each layer
	MTOPT	Type of material properties input = 0 Engineering constants = 1 Matrices A, B (optional), and D are supplied
TABLE	NOTHKV	Number of items in THICK array
	MTBCNT	Number of rows in ITABLE array
	THICK	Lamina thicknesses
	ITABLE	Plate data control table (I,1)--Table number (I,2)--Number of items in table
	T	Plate data (1,J)--E-modulus for direction 1 (2,J)--E-modulus for direction 2 (3,J)--Poisson's ratio (4,J)--G-modulus (G12) (5,J)--fiber angle (degrees)

Common block	Variable	Description
WAVE	MSOPT	List search option = 1 stop search when local minimum is first detected = 2 search complete list for minimum
	NOWAVE	Number of wave values in list
	WAVE	List of wave values to be searched
	IWTYPE	Type of wave list = 1 input as m values = 2 input as λ values
	MLIST	List of m numbers
	VLOAD	Array of variable loads obtained for each wave value
WVSRCH	NTRY	Switch for number of critical wave lengths to seek 0 = only one to find 1 = seeking first critical with two to find 2 = seeking second critical with two to find
	NFLIP	Switch for flipping critical wave length search between two sections
	NHALF	Section in which wave search being made
	BORDR1	The lower bound (half-wave length inverse) for critical wave search
	BORDR2	The upper bound (half-wave length inverse) for critical wave search
	BORDR3	The bound beyond which no sharp dropoff in critical load is permitted
	WAVEP	The critical half-wave length inverse found for first try
	WAVES	A half-wave length inverse to be used initially on second try

Common block	Variable	Description
	WAVET	A half-wave length inverse to be used initially on second try along with WAVES
	VLOADP	The critical minimum load found for first try
	VLOADS	Critical load value corresponding to WAVES
	VLOADT	Critical load value corresponding to WAVET
	HOLDL	Critical load corresponding to HOLDW
	HOLDW	Half-wave length inverse value being held from previous iteration
ZCOM	NLCNT	Counter (initially) and length (finally) for arrays of wave lengths, upper bounds, and critical loads, which are saved for an output summary
	TWAVE	Half-wave lengths array
	TLOAD	Critical load array
	UPPER	Upper bound array
ZERROR	LTRAN	Return address after error detection during problem execution

1.5 BASIC DATA FLOW

Variable	Common block	Where set	Where used
A	ABD	PLTDEF	GALUP PLTCLC RGENER STRAIN
ACON	ACON	DATIN	GALUP
ANGLE	ANGCM	DATIN	PLTDEF
AN11	LOADVL	DC	AROOT PLTCLC RGENER
AN12	LOADVL	DC	AROOT PLTCLC RGENER
AN22	LOADVL	DC	DC AROOT PLTCLC RGENER
B	ABD	PLTDEF	GALUP PLTCLC RGENER STRAIN
BNDLWR	OPTION	DATIN	LOADCL
BNDUPR	OPTION	DATIN	SELECT LOADCL
BORDR1	WVSRCH	WAVFND	SELECT WAVFND

Variable	Common block	Where set	Where used
BORDR2	WVSRCH	WAVFND	SELECT WAVFND
BORDR3	WVSRCH	WAVFND	SELECT WAVFND
CARD	RDCOM	PRERD	PRERD DATIN NEXTC PLTDEF RDTBLE
D	ABD	PLTDEF	GALUP PLTCLC RGENER STRAIN
DONSWI	CNTROL	DATIN	PLTCLC RGENER
DOUBLE	CONTRL	DBLERT	LOADCN
DSTIFF	DSTIFF	DATIN	INFORM MERGEC
HOLDL	WVSRCH	WAVFND	WAVFND
HOLDW	WVSRCH	WAVFND	WAVFND
ICRD	DCARD	DATIN	DATIN
IDISP	INFO	DATIN	INFORM
IEOF	PRECOM	SO352A STRAIN	PRERD STRAIN

Variable	Common block	Where set	Where used
IERFLG	DCARD	DATIN	DATIN
IETYPE	PLATE	DATIN	DATIN PLTDEF INFORM
IKARD	DCARD	DATIN PRERD	PRERD
IPC	CNTROL	DATIN	LOADCL LOADCN DC
IPRLFT	INFO	DATIN	DATIN INFORM
IPRNT1	CONPNT	DC AROOT	AROOT
IPRNT2	CONPNT	DC	RGENER
IPRNT3	CONPNT	DC PLATEC	PLATEC
IPRNT4	CONPNT	LOADCN	DC
IPRNT5	CONPNT	LOADCL	LOADCN
IPRRHT	INFO	DATIN	DATIN INFORM

Variable	Common block	Where set	Where used
ITABLE	TABLE	DATIN	PLTDEF
IWTYPE	WAVE	DATIN	DATIN INFORM LOADCL
IX	ICK	LOADCL DC	LOADCN DC
JPC	CNTROL	DATIN	SO352A DATIN SELECT
KDNO	RDCOM	DATIN NEXTC PLTDEF RDTBLE	DATIN NEXTC PLTDEF RDTBLE
KDNT	RDCOM	PRERD	PLTDEF RDTBLE
KEND	INFO	WAVFND LOADCL	LOADCL
KREAD	PRECOM	SO352A PRERD	PRERD
KTITL	DCARD	PRERD	PLTDEF LOADCL
KXT	PROOTC	PLATEC	PLTCLC
KXY	PROOTC	AROOT PLTCLC	AROOT PLTCLC RGENER DTC

Variable	Common block	Where set	Where used
KXZ	PROOTC	AROOT	AROOT RGENER DTC
LDOPT	OPTION	DATIN	DATIN INFORM GALUP DC STRAIN
LRTRN	DBTRAN	DC	DBLERT
LTRAN	ZERROR	S0352A	ERROR
MATXB	ABD	PLTDEF	AROOT
MLIST	WAVE	DATIN	DATIN INFORM LOADCL
MRLIST	MERGE	DATIN	MERGEC
MSOPT	WAVE	DATIN	DATIN SELECT LOADCL
MTBCNT	TABLE	DATIN	PLTDEF
MTOPT	STRCM	PLTDEF	STRAIN
NCLS	MERGE	DATIN	LOADCL MERGEC
NDIR	NDIR	SELECT WAVFND	SELECT WAVFND LOADCL

Variable	Common block	Where set	Where used
NFLIP	WVSRCH	WAVFND	WAVFND
NHALF	WVSRCH	WAVFND	WAVFND
NLAY	STRCM	PLTDEF	STRAIN
NLCNT	ZCOM	SELECT LOADCL	LOADCL
NND	NND	DC	DC
NOANG	ANGCM	DATIN	PLTDEF
NOTHKV	TABLE	DATIN	PLTDEF
NOWAVE	WAVE	DATIN WAVFND	DATIN SELECT GALUP LOADCL
NPAGE	DCARD	PRERD PLTDEF LOADCL	PRERD PLTDEF LOADCL
NR	PROOTC	DC AROOT	AROOT
NRWS	MERGE	DATIN	LOADCL MERGEC
NT	PROOTC	AROOT	AROOT
NTRY	WVSRCH	WAVFND	WAVFND
NZERO	CONTRL	DC	LOADCN
P	PROOTC	AROOT	AROOT PLATEC

Variable	Common block	Where set	Where used
PIX	PROOTC	AROOT	AROOT
PLONG	PLATE	DATIN	INFORM
POSTVE	CONTRL	DC	LOADCN
R	RC	RGENER	RGENER DTC
RADIUS	PLATE	DATIN	DATIN INFORM GALUP PLTCLC RGENER
RIX	OPTION	DATIN	INFORM DC
RIXY	OPTION	DATIN	INFORM DC
RIY	OPTION	DATIN	INFORM DC
RMA	CWAVAL	LOADCL	PLTCLC RGENER
RXXY	OPTION	DATIN	INFORM DC STRAIN
RXY	OPTION	DATIN	INFORM DC STRAIN
RYXY	OPTION	DATIN	INFORM DC STRAIN
SLW	BOUND	LOADCL	LOADCL

Variable	Common block	Where set	Where used
SUP	BOUND	LOADCL	LOADCL
SWAVE	INFO	DATIN	INFORM LOADCL
T	TABLE	DATIN	PLTDEF
TCARD	PRECOM	PRERD	PRERD
THICK	TABLE	DATIN	PLTDEF
THTA	STRCM	PLTDEF	STRAIN
TLOAD	ZCOM	LOADCL	LOADCL
TWAVE	ZCOM	LOADCL	LOADCL
UPBND	BOUND	GALUP	LOADCL
UPPER	ZCOM	LOADCL	LOADCL
VLOAD	WAVE	WAVFND LOADCL	WAVFND LOADCL
VLOADP	WVSRCH	WAVFND	WAVFND
VLOADS	WVSRCH	WAVFND	WAVFND
VLOADT	WVSRCH	WAVFND	WAVFND
VMIN	INFO	LOADCL	LOADCL STRAIN
WAVE	WAVE	DATIN SELECT WAVFND	DATIN SELECT WAVFND GALUP

Variable	Common block	Where set	Where used
WAVEP	WVSRCH	WAVFND	WAVFND
WAVES	WVSRCH	WAVFND	WAVFND
WAVET	WVSRCH	WAVFND	WAVFND
WIDE	INFO	DATIN	INFORM
WIDTH	PLATE	DATIN	DATIN INFORM GALUP
XL1	INFO	DATIN	DATIN
XL2	INFO	DATIN	DATIN

1.6 PROGRAM AND SUBPROGRAM DESCRIPTIONS

Each subroutine is described in this section. The descriptions are placed in alphabetical order.

Contributions made by Paul Lu, Claude Gagnon, and Edith Shook of Boeing Computer Services are gratefully acknowledged.

Subroutine AROOT

Purpose: To find the roots of the characteristic equations associated with the stability equation (Eq. A.37, ref. 1)

Called From: DC

Input:
(a) Calling sequence–none
(b) COMMON–/ABD/, MATX B
/CONPNT/, IPRNT1
/LOADVL/ AN11, AN12, AN22
/PROOTC/ NR

Discussion: The characteristic roots are obtained by a root finder. The roots are then examined for conjugate pairs and the occurrence of double roots. For flat plates with zero B matrix the problem is uncoupled into two fourth-order problems.

Routined Called:
ZARK2
DBLERT
ERROR

Output:
(a) Calling sequence–none
(b) COMMON–/PROOTC/, NR, NT, KXZ, KXY, PIX, P
(c) User I/O files output–check print of load values and characteristic roots.
Error message on root searching.

Subroutine ASTAR (ASTAR (AST, A, B, D, IBAD)

Purpose: To perform calculations $AST = A - B \cdot D^{-1} \cdot B$

Called From: STRAIN
GALUP

Input: Calling sequence
A—extensional stiffness matrix (3 x 3)
B—coupling stiffness matrix (3 x 3)
D—bending stiffness matrix (3 x 3)

Discussion: None

Routines Called: SIMEQ

Output: AST—reduced matrix
IBAD—error return (0 = ok, 1 = error)

Subroutine CALVET (A, ER, IPR)

Purpose: To solve a 3 x 3 homogeneous complex system of equations $A \cdot X = 0$ by inverse iteration technique.

Called From: PLTCLC

Input: Calling sequence

A–3 x 3 complex array containing given matrix

Discussion: The given square matrix A is decomposed into lower and upper triangular matrices, L and U, by Crout's method with partial pivoting. Then Wielandt's inverse iteration for finding the eigenvector is used to generate the required solution vector which is normalized to the third component.

Routines Called: None

Output: Calling sequence

V– complex array returning the solution vector

IPR–working array for pivoting information

Function CDTM (CA, NR, N, V)

Purpose: To evaluate the determinant of a complex square matrix

Called From: DTC

Input: (a) Calling sequence

A– elements of matrix stored in a complex array

NR–2 x NC (NC-maximum row dimension of complex array A)

N– dimension of the square matrix

V– a scratch array of length $\geqslant$N

(b) COMMON–none

Discussion: The given square matrix A is decomposed into lower and upper triangular matrices, L and U, by Crout's method with partial pivoting and row equilibration. So we have

$$\det(PA) - \det(L)\det(U) = \prod_{i=1}^{n} \ell_{i,i}$$

where PA = LU and P is a product of permutation matrices, and

$$\det(A) = (-1)^k \prod_{i=1}^{n} \ell_{i,i}$$

where k is the total number of row permutations performed on A. The routine uses the standard FORTRAN convention for storing complex matrices, but it does not use FORTRAN complex arithmetic. The magnitude of real and imaginary part of the determinant value must be between the lower and the upper bounds of the floating point numbers on the machine. CDTM is typed complex.

Routines Called: VIPDR

Output: Y = CDTM (CA, NR, N, V)

Y– the complex determinant value

Subroutine CHMDET (A, NR, N, DN, D, ID, NND)

Purpose: To compute the determinant of a complex Hermitian matrix, and to find the number of negative diagonal elements.

Called From: DC

Input: Calling sequence

A– two-dimensional complex array (The upper triangular portion contains the upper triangle of the given Hermitian matrix.)

NR–maximum row dimension of the complex array A

N– actual order of the given Hermitian matrix

Discussion: A complex analog of the symmetric gaussian elimination algorithm is used. The given Hermitian matrix A is decomposed to produce the diagonal elements d_{ii} of the matrix D as follows:

$$A = LDU \qquad (1)$$

where D is a diagonal matrix, L is a unit complex lower triangular matrix, and U = L* is the conjugate transpose of L. The diagonal elements d_{ii} are real because the complex matrix A is Hermitian.

Since $\det(L)_n = \det(U) = 1$,

$$\det(A) = \prod_{i=1} d_{ii} \qquad (2)$$

In the routine CHMDET the product in equation (2) is expressed in a form $\det(A) = a \cdot 2^b$ where $1/16 \leqslant |a| < 1$, to avoid underflow or overflow. The number of negative diagonal elements is counted in the process of decomposition.

Routines Called: None

Output:

A–	the lower triangular portion contains the matrix L without diagonal and the upper triangular portion is left unchanged
DC–	the reciprocals of the elements of the diagonal matrix D
D–	the fractional part a of the determinant - $a \cdot 2^b$. It is set equal to zero if decomposition failed.
ID–	the exponential part b of the determinant - $a \cdot 2^b$
NND–	number of negative diagonal elements

Subroutine COMCHK (CARD, NCOM)

Purpose:	To check certain input cards for commas and slashes
Called from:	PRERD
Input:	Calling sequence
	CARD—array of Hollerith data from a data input card
Discussion:	A data input card that is normally fixed field is checked for commas and slashes to determine if it has been input as a free field card.
Output:	Calling sequence
	NCOM—an indicator whose value is 0 (no commas or slashes) or 1 (commas or slashes).

Program DATIN

Purpose: To read a data set and set up the problem from it to be worked

Called From: SO352A

Input:

(a) Calling sequence–none

(b) COMMON–/RDCOM/ CARD, KDNT

Discussion: The following functions are performed on the preread cards:

(1) C2 card content is placed into IPC array

(2) C3 card content is placed into JPC array

(3) Load case information constructed LC card

(4) W1, W2, W3 cards supply wave search information

(5) BL and BR supply the information for construction of merge list

(6) Tables for lamina thickness, material properties, and fiber angles are processed

(7) P1 card is processed

Routines Called:

PRERD
SECOND
RDTBLE
ASIN
PLTDEF

Output:

(a) Calling sequence–none

(b) COMMON–/ANGCM/, NOANG, ANGLE
/CNTROL/, DONSWI, IPC, JPC
/DCARD/, IKARD, IERFLG
/INFO/, WIDE, XL1, XL2, SWAVE, IPRLFT, IPRRHT
/PLATE/, IETYPE, PLONG, WIDTH, RADIUS
/TABLE/, NOTHKV, MTRCNT, THICK, ITABLE, T
/DSTIFF/, DSTIFF
/MERGE/, NRWS, NCLS, MRLIST
/OPTION/, LDOPT, BNDLWR, BNDUPR, RIX, RIY, RIXY, RXY, RXXY, RYXY

/WAVE/, MSOPT, NOWAVE, WAVE, IWTYPE, MLIST
/ACON/, ACON
/RDCOM/, KDNO

(c) User I/O files output—diagnostics and error messages

Subroutine DBLERT

Purpose:	To serve as error trap for double root detection
Called From:	AROOT
Input:	(a) Calling sequence–none (b) COMMON–/DBTRAN/LRTRN
Discussion:	In a double root situation, the condition is flagged and return is made to load control routine to attempt to avoid the problem.
Routines Called:	None
Output:	(a) Calling sequence–none (b) COMMON–/CONTRL/, DOUBLE (c) User I/O files output–error message indicated double root condition.

Function DC (VLOAD, DBMA, M1, N1, DX, IDX)

Purpose: To calculate the load configuration for a given load option and varying load component and to control the formation of and the determinant calculation of the resulting stiffness matrix.

Called From: LOADCL through LOADCN

Input:
(a) Calling sequence
VLOAD–varying load component
DBMA–work array for determinant calculation
M1–row dimension of DBMA array
N1–column dimension of DBMA array

(b) COMMON–/CNTROL/, IPC
/CONPNT/, IPRNT4
/CONTRL/, DOUBLE
/ICK/, IX
/OPTION/, RIX, RIY, RIXY, RXY, RXXY, RYXY

Discussion: The subprogram determines conditions that might occur in the determinant calculation such as: zero determinant and double roots among characteristic equation associated with stability equations.

Routines Called:
PLATEC
MERGEC
PRINTC
CHMDET

Output:
(a) Calling sequence
DX–the exponential part b of the determinant $a \cdot 2^b$
IDX–the fractional part a of the determinant $a \cdot 2^b$

(b) COMMON–/CONPNT/, IPRNT1, IPRNT2, IPRNT3
/CONTRL/, NZERO, POSTVE
/DBTRAN/, LRTRN
/ICK/, IX
/LOADVL/, AN11, AN12, AN22
/PROOTC/, NR
/NND/, NND

(c) User I/O files output–summary of determinant calculation

Function DTC (P)

Purpose:	To obtain, for a complex number P, the determinant of the matrix associated with the stability equations (eq A.37, ref. 1).
Called From:	AROOT
Input:	(a) Calling sequence—P, a complex number (b) COMMON–/PROOTC/, KXY, KXZ /RC/, R
Discussion:	For a complex number P, the matrix for the stability equations is generated by RGENER. Next, depending on the element type, the determinant for a 3 x 3 or 2 x 2 or 1 x 1 matrix is obtained.
Routines Called:	CDTM RGENER
Output:	Y = DTC (P) Y— value of determinant

Subroutine ERROR (NAME, NO)

Purpose: To handle fatal error conditions

Called From: SOLVEC, LOADCN, STRAIN, AROOT, GALUP

Input: Calling sequence

NAME–name of routine where error was detected

NO–error number

Discussion: The routine name and error number is printed. A return to S0352A is made.

Routines Called: None

Output:

(a) Calling sequence–none

(b) COMMON–none

(c) User I/O files ouput–routine name and error number

Program GALUP

Purpose: To calculate an upper bound for a clamped plate by the Galerkin method. This upper bound is used in the calculation procedure which finds the critical load.

Called From: SELECT

Input:

(a) Calling sequence–none

(b) COMMON–/ABD/, A, B, D
/PLATE/, WIDTH, RADIUS
/WAVE/, NOWAVE, WAVE
/ACON/, ACON
/OPTION/, LDOPT

Discussion: The A, B, and D, matrices are used for the calculation of required constants. If the $B_{1,6}$ term or $B_{2,6}$ term is nonzero, a modified B matrix is determined for use by GALUP. Required constants differ according to the load option in use.

In essence the Galerkin method results in the following matrix equation:

$$(A + \lambda B) \{ W \} = 0$$

The minimum positive eigenvalue is found. This is used for the upper bound.

Routines Called:

ASTAR
REDUC3
EECM
GALUP

Output:

(a) Calling sequence–none

(b) COMMON–/BOUND/, UPBND

Subroutine INFORM

Purpose: To summarize the input options.

Called From: PLTDEF

Input:
(a) Calling sequence–none
(b) COMMON–/DCARD/, KTITL, NPAGE
/DSTIFF/, DSTIFF
/OPTION/, LDOPT, BNDLWR, BNDUPR, RIX, RIY, RIXY
RXY, RXXY, RYXY
/PLATE/, IETYPE, PLONG, WIDTH, RADIUS
/WAVE/, IWTYPE, MLIST
/INFO/, WIDE, SWAVE, IPRLFT, IPRRHT

Discussion: None

Routines Called: None

Output:
(a) Calling sequence–none
(b) COMMON–none
(c) User I/O files output–summary print

Program LOADCL

Purpose: To control the search for a minimum buckling load value over a range of half-wave values.

Called From: SELECT

Input:

(a) Calling sequence–none

(b) COMMON–/BOUND/, UPBND
/CNTROL/, IPC
/MERGE/, NRWS, NCLS
/OPTION/, BNDLWR, BNDUPR
/WAVE/, MSOPT, NOWAVE, WAVE, IWTYPE, MLIST
/DCARD/, KTITL, NPAGE
/NDIR/, NDIR

Discussion: The search runs on basis of saying either the minimum is first half-wave value for which the next wave value has a larger buckling load, or the minimum is the half-wave value with the smallest buckling load where all wave values are searched.

Routines Called: LOADCN
DC

Output:

(a) Calling sequence–none

(b) COMMON–/BOUND/, SUP, SLW
/CONPNT/, IPRNT5
/CWAVAL/, RMA
/ICK/, IX
/WAVE/, VLOAD
/INFO/, SWAVE, KEND, VMIN

(c) User I/O files output–summary of minimum load search

Subroutine LOADCN (DB, DBMA, M1, N1, IP, SUP, SLW)

Purpose: For a given interval, to find the buckling load for the interval to a specified tolerance.

Called From: LOADCL

Input:

(a) Calling sequence

DB—name of function program which calculates determinant
DBMA—work array for determinant
M1—row size of determinant
N1—column size of determinant
SUP—upper end of given interval
SLW—lower end of given interval

(b) COMMON—/CNTROL/, IPC
/CONPNT/,IPRNT5
/CONTRL/, DOUBLE, NZERO, POSTVE
/ICK/, IX

Discussion: The load search uses a modified bisection technique. When a 0-1 root-crossing situation is detected, an effort is made to improve convergence by choosing a trial load which is nearer the actual buckling load. The program also handles abnormal conditions such as double roots and zero determinant by perturbing the trial load.

Routines Called: ERROR

Output:

(a) Calling sequence

SUP—upper value of calculated interval containing buckling load
SLW—lower value of calculated interval containing buckling load

(b) COMMON—/CONPNT/, IPRNT4

(c) User I/O files output—check print of load search

Subroutine MERGEC (A, M, S, IP)

Purpose: To merge an elemental stiffness matrix into the global stiffness matrix.

Called From: DC

Input:

(a) Calling sequence

A—complex array containing global stiffness matrix

M—row dimension of array A

S—complex array containing elemental stiffness matrix

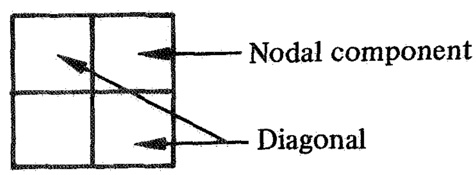
IP—pointer to which side elemental matrix is on.

= 1 Left side

2 Right side

(b) COMMON–/DSTIFF/, DSTIFF

Discussion: The elemental matrix is merged in by nodal components with the diagonal component being modified by the appropriate nodal stiffness matrix (if any).



Elemental matrix (8 x 8)

Routines Called: STOREC

Output: Calling sequence

A—complex array containing global stiffness matrix

Function NEXTC (IN, IOUT, IA, IPOS)

Purpose: To read table pointer card as needed and return one character each time entered.

Called From: TBPOINT

Input:
(a) Calling sequence
IPOS—location of character in string
(b) COMMON—/RDCOM/, CARD, KDNO

Discussion: IPOS must be >78 for first entry.

Routines Called: None

Output
(a) Calling sequence
NEXTC—character status flag
if IA = number, NEXTC = 1R9
= character, NEXTC = IA
IA—the IPOS character from the string
(b) COMMON—/RDCOM/, KDNO

Subroutine PAC (A, I, J, B)

Purpose: To pack the (J-I+1) right-most bits of the word B into bit positions I-J of the word A with the remaining bits unchanged.

Called From: DATIN
STRMOV
STOREC

Input: Calling sequence
- I—left position
- J—right position
- B—word from which packing is being done

Discussion: Routine is in COMPASS using RUN linkage conventions.

Routines Called: None

Output: Calling sequence
- A—word into which packing is being done

Subroutine PLACE (A, DUM)

Purpose: To place input data into A, B, or D array.

Called from: PLTDEF

Input: Calling sequence

DUM–array of input values

Discussion: None

Output: Calling sequence

A–array filled with input values

Subroutine PLATEC (ST, XD, XF)

Purpose: To control the generation of columns of the buckling displacements and corresponding loads and produce the resulting stiffness matrix.

Called From: DC

Input: (a) Calling sequence–none

(b) COMMON–/CONPNT/, IPRNT3
/PROOTC/, NT, KXY

Discussion: The equations for buckling displacements as defined by equation A.45 (ref. 1) and corresponding loads defined by equation A.51 (ref. 1) are generated and the stiffness matrix is obtained by the relationship specified in equations A.52 and A.53 (ref. 1).

Routines Called: PLTCLC
PRINTC
SOLVEC

Output: (a) Calling sequence
ST–8 x 8 complex array containing stiffness matrix
XD–8 x 8 complex array containing buckling displacements
XF–8 x 8 complex array containing corresponding loads

(b) COMMON–/PROOTC/, KXT

Subroutine PLTCLC (P, DL, FL, DR, FR)

Purpose: For a P value, to generate the columns of the deflection and force matrix for the right and left sides of the plate.

Called From: PLATEC

Input: (a) Calling sequence—P - P value

(b) COMMON—/ABD/, A, B, D
/CNTROL/, DONSWI
/CWAVAL/, RMA
/LOADVL/, AN11, AN12, AN22
/PLATE/, WIDTH, RADIUS
/RC/, R
/PROOTC/, KXT, KXY

Discussion: The deflection matrix represents equations A.40, A.41, A.42 and A.43 of reference 1. The force matrix represents equations A.46, A.47, A.48, and A.49 of reference 1. In the case of B = 0 and flat plate the equations have been modified accordingly.

Routines Called: RGENER
CALVET

Output: (a) Calling sequence
DL—complex matrix containing left-side deflection column
FL—complex matrix containing left-side force column
DR—complex matrix containing right-side deflection column
FR—complex matrix containing right-side force column

(b) COMMON—/PROOTC/, KXY

Subroutine PLTDEF (MATOPT, INOPT, LAYERS, SM2X, ZNX, IER)

Purpose: To produce the plate element extensional, coupling, and bending stiffness matrices.

Called From: DATIN

Input:
(a) Calling sequence
MATOPT—type of material properties input
INOPT—input mode when MATOPT = 0
LAYERS—number of laminas in plate
(b) COMMON—/PLATE/, IETYPE
/TABLE/, NOTHKV, MTBCNT, THICK, ITABLE, T
/DCARD/, KTITL, NPAGE
/RDCOM/, CARD, KDNT, KDNO
/ANGCM/, NOANG, ANGLE
/CNTROL/, IPC

Discussion: The A, B, D matrices are either input directly or calculated from material properties input by P2, P3, or LM cards using equations A.4, A.8, A.9, and A.10 (ref. 1).

Routines Called:
TBPOINT
INFORM
PLACE

Output:
(a) Calling sequence
IER—status flag (0 = no error) (1 = errors)
(b) COMMON—/ABD/, A, B, D, MATXB
/STRCM/, NLAY, THTA, MTOPT
(c) User I/O files output—summary of element input, print of A, B, and D matrices

Program PRERD

Purpose:	To provide a preliminary processing of the input cards.
Called From:	DATIN
Input:	(a) Calling sequence—none (b) COMMON—/RDCOM/ KREAD, TCARD, IEOF
Discussion:	PRERD brings in a data set from input cards, reorders the data set to a specified order, and checks to see if all required input cards were present.
Routines Called:	DATE COMCHK
Output:	(a) Calling sequence—none (b) COMMON—/DCARD/ KTITL /RDCOM/ KREAD, IEOF /PRECOM/ CARD, KDNT, KDNO

Subroutine PRINTC (A, NROW, NCOL, TITLE, NIZ)

Purpose: To print a rectangular complex matrix stored in the array A.

Called From: DC
PLATEC

Input: Calling sequence
A–two-dimensional complex array containing matrix
NROW–number of rows in matrix
NCOL–number of columns in matrix
TITLE–one word containing matrix title
NIZ–maximum row dimension

Discussion: The matrix is printed row wise, four pairs per row.

Routines called: None

Output:
(a) Calling sequence–none
(b) COMMON–none
(c) User I/O files output–print of matrix

Subroutine RDTBLE (IU, ITBL, CARD, T, MAX, L, IER)

Purpose: To read floating point or integer data from columns 6-75 of card format . . . , array with format . . . , . . . , value, . . ./

Called From: DATIN

Input: (a) Calling sequence

KARD–array containing first card image

MAX–maximum size of array T

ITBL–name of Table T

(b) COMMON–/RDCOM/, CARD, KDNO, KDNT

Discussion: Delimiters are commas, end of physical card, and slash (/). The number of significant digits is limited to 14. Blanks are ignored. The incoming values are reformatted so they can be read by a FORTRAN format statement.

Routines Called: STRMOV

Output: T–array containing floating point numbers

L–number of values stored in T

IER–status flag

Subroutine REDUC3 (A, B, D, N, NR, IER)

Purpose: To reduce the generalized complex eigenproblem $Ax = \lambda Bx$, where A is a Hermitian matrix and B is a positive definite Hermitian matrix, to a complex Hermitian eigenproblem $CY = \lambda Y$

Called From: GALUP

Input: Calling sequence

- A—a two-dimensional complex array (The upper triangular portion contains the upper triangle of the given Hermitian matrix A. If the given matrix is real, the imaginary part of A should be set to zero.)
- B—a two-dimensional complex array containing the given matrix B, similar to setup for matrix A
- NR—maximum row dimension of the complex arrays A and B
- N—actual order of the given matrix

Discussion: First, the complex analog of Cholesky decomposition is applied to B, $B = LL^*$ where L is a lower triangular matrix and L^* is the conjugate transpose of L. By forward substitutions, the transpose of the upper triangle of the matrix G is formed, $LG = A$. Finally, the upper triangle of the required complex Hermitian matrix is computed by solving the equation $CL^* = G$.

Routines Called: None

Output: Calling sequence

- A—the desired complex Hermitian matrix C is in the upper triangular portion
- B—the upper triangular portion is as input and the lower triangular portion contains the matrix L without diagonals
- D—the real diagonal elements of the lower triangular matrix L
- IER—status flag
  - = 1 successful return
  - = 0 the B matrix appears not to be positive definite

Subroutine RGENER (ALPHA)

Purpose: To generate coefficients of R matrix (eq. A.37, ref. 1) for a complex number ALPHA and a load configuration.

Called From: DTC
PLTCLC

Input: (a) Calling sequence–ALPHA–complex number

(b) COMMON–/ABD/, A, B, D
/CONPNT/, IPRNT2
/CONTRL/, DONSWI
/CWAVAL/, RMA
/LOADVL/, AN11, AN12, AN22
/PLATE/, RADIUS
/PROOTC/, KXZ, KXY

Discussion: Depending on element type, a 3 x 3 matrix is generated (curved plate or plate with B $\neq$ 0). If B = 0 and flat plate, a 2 x 2 submatrix is generated in upper 2 x 2 of R and 1 x 1 submatrix is generated in 3, 3 spot of R.

Routines Called: None

Output: (a) Calling sequence–none

(b) COMMON–/RC/, R

(c) User I/O files output–check print of R matrix

Program SELECT

Purpose: SELECT is the monitor program which choses the various sections of load calculation overlay to be executed.

Called From: S0352A

Input:
(a) Calling sequence–none
(b) COMMON–/CNTROL/, JPC
/WAVE/, MSOPT, NOWAVE, WAVE
/OPTION/, BNDUPR
/NDIR/, NDIR
/WVSRCH/, BORDR1, BORDR2

Discussion: Detailed functions of load overlay
(1) Picking wave values for use in finding a minimum critical load
(2) Upper-bound calculation
(3) Critical load calculation

Routines Called:
WAVFND
GALUP
LOADCL

Output:
(a) Calling sequence–none
(b) COMMON–/NDIR/, NDIR
/WAVE/, WAVE

Subroutine SOLVEC (X, A, B, N, M)

Purpose: To solve matrix equation $X \cdot A = B$.

Called From: PLATEC

Input: Calling sequence

A—complex array containing A matrix (M x M order)

B—complex array containing B matrix (N x M order)

N—number of rows in B matrix, $N \leqslant 8$

M—number of rows in A matrix, $M \leqslant 8$

Discussion: To utilize a standard complex linear equation solver, the original problem is transformed to an equivalent problem ($A^T X^T = B^T$). X^T is solved for and then transformed to obtain the result, X.

Routines Called: PRINTC
ERROR
CXINV

Output: X—complex array containing X matrix (result)
If an apparent singularity is encountered in the decomposition of A^T, a call to ERROR is made.

Subroutine SORT(TWAVE, UPPER, TLOAD, NLCNT, ALOAD, AUPPER)

Purpose:	To reorder the half-wave lengths and corresponding minimum load values in ascending order of the half-wave lengths.
Called From:	LOADCL
Input:	Calling sequence: TWAVE–array of half-wave lengths UPPER–array of upper bounds TLOAD–array of critical loads NLCNT–size of the arrays
Discussion:	A simple sort is accomplished
Routines Called:	None
Output:	Calling sequence: TWAVE, UPPER, and TLOAD reordered ALOAD–minimum critical load AUPPER–upper bound associated with minimum critical load

Subroutine STOREC (A, M, W, I, J)

Purpose: To merge nodal components of element stiffness matrix into global stiffness matrix.

Called From: MERGEC

Input: (a) Calling sequence

A–array containing global stiffness matrix

M–row dimension of global stiffness matrix

W–array containing nodal component

I–left node number of nodal component

J–right node number of nodal component

(b) COMMON–/MERGE/, NRWS, NCLS, MRLIST

Discussion: The nodal component node numbers are looked up in global node list to obtain the component merge position.

Routines Called: PAC

Output: Calling sequence

A–array containing global stiffness matrix

Program STRAIN

Purpose: To process the calculation of the critical strains.

Called From: SO352A

Input:

(a) Calling sequence–none

(b) COMMON–/ABD/, A, B, D
/OPTION/, LDOPT, RIX, RIY, RIXY, RXY, RXXY, RYXY
/STRCM/, NLAY, THTA, MTOPT
/INFO/, VMIN
/PRECOM/, IEOF

Discussion: The strains are calculated using equation A.56 (ref. 1)

Routines Called:

ASTAR
SIMEQ
ERROR

Output:

(a) Calling sequence–none

(b) COMMON–/PRECOM/, IEOF

(c) User I/O files output–strain summary print

Subroutine STRMOV (S1, C1, N, S2, C2)

Purpose: To move a string of characters from one array to another.

Called From: RDTBLE

Input: Calling sequence

- S1—array containing the string to be moved
- C1—an integer specifying the position of the first character to be moved relative to the first position of the array
- N—number of characters to be moved
- C2—an integer specifying the position of the first character is S2 which is to receive the characters from S1.

Discussion: None

Routines Called: PAC
UNPAC

Output: Calling sequence

- S2—Receiving array name

Program SO352A

Purpose:	SO352A is the monitor program which chooses the various sections of the analysis to be used.
Called From:	
Input:	COMMON/CONTROL/, JPC COMMON/PRECOM/, IEOF
Discussion:	The program terminates by reading an end of file on input.
Routines Called:	DATIN SELECT STRAIN EXIT
Output:	(a) Calling sequence–none (b) COMMON–none

Subroutine TBPOINT (IN, IOUT, MAX, IPN, IER)

Purpose: To construct a table of pointers from the P3 or LM card.

Input: Calling sequence

MAX–required length of table

Discussion: Table of pointers may have the following format:

$(I_1, I_2, , , I_3/J_1, , J_2, J_3, J_4/K_1, , , , K_2)$

Between each slash there must be the same number of entries. The result is

IPN $(1,1) = I_1$,	$(1,2) = J_1$,	$(1,3) = K_1$
$(2,1) = I_2$,	$(2,2) = J_1$,	$(2,3) = K_1$
$(3,1) = I_2$,	$(3,2) = J_2$,	$(3,3) = K_1$
$(4,1) = I_2$,	$(4,2) = J_3$,	$(4,3) = K_1$
$(5,1) = I_3$,	$(5,2) = J_4$,	$(5,3) = K_2$

Routines Called: NEXTC

Output:

(a) Calling sequence

IPN–array containing table of pointers

(b) COMMON–name

(c) User I/O files output–error messages

Subroutine UNPAC (A, I, J, B)

Purpose: To extract bits I-J from word A and place them right adjusted into the word B with the rest of B being set to zero.

Called From: STRMOV

Input: Calling sequence

- A—source of bits to be placed in B
- I—first bit position of string from A
- J—last bit position of string from A

Discussion: UNPAC is coded in COMPASS using RUN linkage convention.

Routines Called: None

Output: Called sequence

- B—word receiving extracted bit string from A

Subroutine VIPDR (A, INCA, B, INCB, N, C)

Purpose: To calculate the inner product of two complex vectors in double precision.

Called From: CDTM

Input: (a) Calling sequence

A–first location of vector 1

INCA–storage increment between successive elements of vector 1

B–first location of vector 2

INCB–storage increment between successive elements of vector 2

N–number of elements in vector 1 or vector 2

(b) COMMON–none

Discussion: For efficiency the routine is coded in COMPASS using RUN linkage conventions. The result is stored in C, C + 1 (C should be declared double precision in the calling program).

Routines Called: None

Output: (a) Calling sequence

C–first location of double precision result

(b) COMMON–none

Program WAVFND

Purpose: The WAVFND subroutine selects the wave values (half-wave length inverses) to be used in the search for a local minimum critical load.

Called From: SELECT

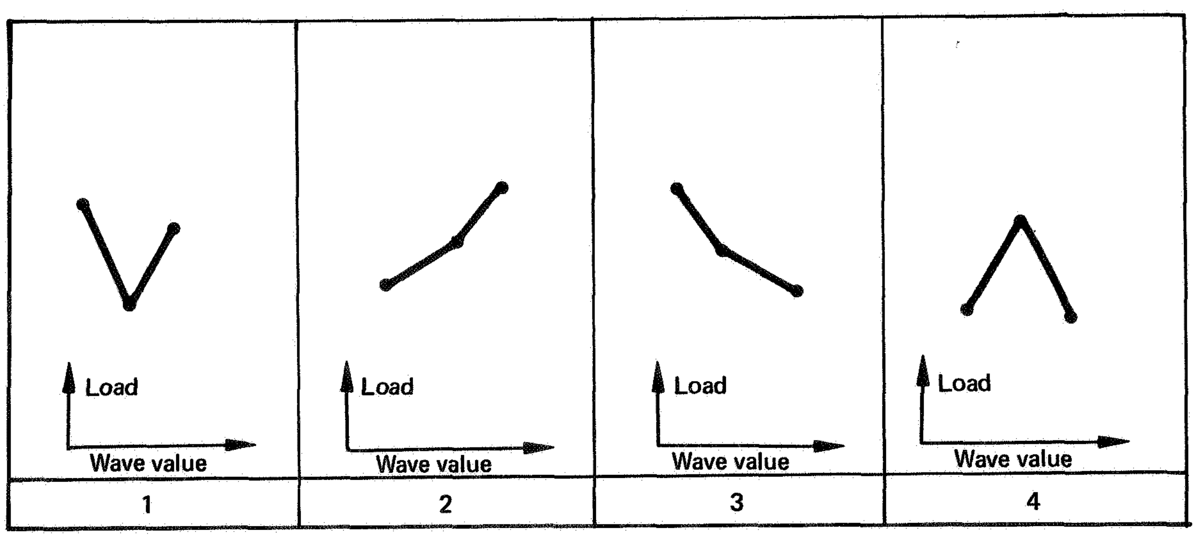
Input: (a) Calling sequence—none

(b) COMMON—/NDIR/, NDIR
/WAVE/, WAVE, VLOAD

Discussion: Given three wave values in the data input, the WAVFND subroutine first establishes upper and lower limits on the wave values that it will select. A third limit is established. Beyond this third limit a sudden dropoff in any critical load value found will terminate the search for a minimum critical load.

Critical load values are calculated elsewhere in the BUCLAP2 program. On return to WAVFND for a second pass, the set of three wave value-critical load value pairs is classified as to which of four configurations it belongs. See the following diagram.

Configurations



In configuration 1 the minimum load value is sought within the limits of the low and high wave value. In configuration 2 the minimum is sought at lower wave values until the lower limit is hit or until a higher load value is found (which converts the configuration to type 1). In configuration 3 the minimum is sought at higher wave values until the upper limit is hit or until a higher load value is found (which converts the configuration to type 1). In the case of configuration 4, it is treated as a combination of configurations 2 and 3 and the lower of the two minimums from each configuration is found.

There is no guarantee that the lowest minimum is found if more than one minimum can exist. (Multiple local minimums do occur in BUCLAP2 problems.)

Routines Called: None

Output:

(a) Calling sequence—none

(b) COMMON—/NDIR/, NDIR
/WAVE/, NOWAVE, WAVE, VLOAD
/INFO/, SWAVE, KEND
/WVSRCH/, NTRY, NFLIP, NHALF, BORDR1, BORDR2, BORDR3, WAVEP, WAVES, WAVET, VLOADP, VLOADS, VLOADT, HOLDL, HOLDW

Subroutine ZARK2 (N, MAX, EP1, EP2, FUN, I , ANSA, FANSA)

Purpose: To find N zeros of an arbitrary complex valued function of a complex variable.

Called From: AROOT

Input: Calling sequence

N—number of zeros to be found

MAX—maximum number of iterations to be executed in finding any one zero

EP1, EP2—convergence tolerances (Iteration will be terminated if $|X_i - X_{i-1}| \leqslant$ EP1. ($|X_i|$) or $|F(X_i)| \leqslant$ EP2. X_i and X_{i-1} are the last two approximations to the zero.)

FUN—complex function subprogram with complex parameter X which returns FUN = F (X)

Discussion: Muller's method of successive approximation with quadratic complex polynomials. The Newtonian form of the approximating polynomial is used. Successive zeros are found by factoring out previously found zeros. That is, if F(Z) is the original function, and a zero Z_o is computed, then the next zero will be found for the function $F(Z)/(Z - Z_o)$. In general, if Z_i, i = 0, ..., n, are calculated zeros, the next zero will be sought for the function.

$$F(Z) / \prod_{i=0}^{n} (Z - Z_i)$$

The complex conjugate of a complex root is sought immediately.

Routines Called: None

Output: Calling sequence

ANS—N dimensional complex array returning the computed zeros

FANS—N dimensional complex array returning the function values at the computed zeros.

I—status flag

= 0 run successful

= 1 run unsuccessful—failed to converge in maximum iterations

N—number of zeros computed

2.0 PROGRAM VALIDATION

The program BUCLAP2 was validated by running various tests (data input sets unless noted otherwise) such that all major logic path and input options were tested. See reference 2 for data description. The validation testing was done in two ways: execution of actual data and inspection.

2.1 INPUT OPTION FUNCTIONAL TESTS

Card	Field	Option	Test
C1	1	Data set title	H-1
C2	4	α root check print	H-20
	5	R matrix check print	H-20
	6	X_d, X_f, stiffness check print	H-20
	7	Merged stiffness check print	H-20
	8	Load control check print	H-20
	9	Q print	H-20
C3	1	Plate upper bound only	H-28
	2	Date check only	H-42
	3	Number of buckling iterations	H-10
LC	1	Load case option	
		= 1	H-1
		2	H-2
		3	H-5
		4	H-6
		5	H-7
		6	H-8
		7	H-9
	2	First load value–(non-blank)	H-1
	3	Second load value–(non-blank)	H-6
	4	Lower-bound load	H-1
	5	Upper-bound load	H-1

Card	Field	Option	Test
W1	1	Half-wave input option	
		= 1	H-1
		2	H-3
	2	Loop control	
		= 1	H-10
		2	H-1
		3	H-11
		4	H-5
		5 (wave search)	H-3
	3	Initial m or λ values	H-1
	4	Final m or λ values	H-1
	5	Δ m or Δ λ values	H-4
W2	1-15	Wave number list	H-11
W3	1	Wave length table	H-3
BL	1	Preset boundary condition	
		= SS	H-1
		CL	H-3
		FR	H-29
	2	= 1	H-14
		2	H-12
	3	= 1	H-14
		2	H-12
	4	= 1	H-14
		2	H-12
	5	= 1	H-30
		2	H-14
	6	= 0	H-31
		k_w	H-12
	7	= 0	H-31
		k_θ	H-12
	8	= 0	H-31
		k_v	H-12
	9	= 0	H-31
		k_u	H-12

Card	Field	Option	Test
BR	1	Preset boundary condition	
		= SS	H-1
		CL	H-29
		FR	H-3
	2	= 1	H-14
		2	H-12
	3	= 1	H-14
		2	H-12
	4	= 1	H-14
		2	H-12
	5	= 1	H-30
		2	H-14
	6	= 0	H-31
		k_w	H-12
	7	= 0	H-31
		k_θ	H-12
	8	= 0	H-31
		k_v	H-12
	9	= 0	H-31
		k_w	H-12
TT	1	Table entries	H-3
AT	1	Table entries	H-3
MT	1	Table number	H-3
	2	Table entries	H-3
P1	1	Plate type	
		= 1	H-1
		2	H-4
	2	Number of laminas	H-1
	3	Input format	
		= 0	H-1
		1	H-25

Card	Field	Option	Test
	4	Input option	
		= 0	H-1
		1	H-3
	5	Element length	H-1
	6	Element width	H-1
	7	Element radius	H-4
PA	1	A_{11} value	H-25
	2	A_{12} "	
	3	A_{16} "	
	4	A_{22} "	
	5	A_{26} "	
	6	A_{66} "	
PB	1	B_{11} "	
	2	B_{12} "	
	3	B_{16} "	
	4	B_{22} "	
	5	B_{26} "	
	6	B_{66} "	
PC	1	D_{11} "	
	2	D_{12} "	
	3	D_{16} "	
	4	D_{22} "	
	5	D_{26} "	
	6	D_{66} "	H-25
P2	1	Lamina thickness	H-1
	2	E_{11}	H-1
	3	E_{22}	H-2
	4	V_{12}	H-1
	5	G_{12}	H-1
	6	θ	H-32

Card	Field	Option	Test
P3	First set	Thickness pointers	H-3
	Second set	Material pointers	H-3
	Third set	Angle pointers	H-3
LA	1	Table entries	H-83
LM	1	Table entries	H-83
LT	1	Table entries	H-83
END	1	End of data set card	H-1

2.2 DIAGNOSTIC FUNCTIONAL TESTS

Error number	Test
1	H-3
2	H-42
3	H-43
4	H-52
5	H-45
6	H-46
7	H-47
8	H-48
9	H-49
10	H-50
11	H-50
12	H-50
13	H-51
14	H-44
15	H-53
16	H-49
17	H-54
18	H-54
19	H-54
30	H-55
31	H-56
32	H-54
33	H-57
34	H-58
35	H-55
40	H-59
41	H-60 and H-61
42	H-34

Error number	Test
50	H-62
51	H-38
52	H-39
53	H-40
54	H-37
60	H-35
61	H-67
62	H-68
70	By inspection
71	By inspection
75	H-63
80	By inspection
81	By inspection
82	H-41
83	By inspection
90	By inspection
91	By inspection
92	By inspection
95	By inspection
101	By inspection
102	H-62
105	H-69

2.3 PROGRAM FUNCTIONAL TESTS

Program functional tests are tests of possible paths through each subroutine. They are listed in an alphabetical order of subroutines.

Routine	Configuration	Test
AROOT	1. Flat plate with B = 0	H-1
	2. Flat plate with $B \neq 0$	H-2
	3. Check print of α root information	H-20
	4. α root which is real only	H-74
	5. α root which is pure imaginary	H-74
	6. α root which is arbitrary complex	H-74
ASTAR	See description	H-1
CALVET	See description	H-1
CDTM	See description	H-1
CHMDET	See description	H-1
DATIN	1. C1 card present	H-1
	2. C1 card not present - error	H-33
	3. C2 card present	H-1
	4. C2 card not present	H-3
	5. C3 card present	H-1
	6. C3 card not present	H-3
	7. LDOPT = 1	H-1
	8. LDOPT = 2	H-2
	9. LDOPT = 3	H-5
	10. LDOPT = 4	H-6
	11. LDOPT = 5	H-7
	12. LDOPT = 6	H-8
	13. LDOPT = 7	H-9
	14. IWTYPE = 1	H-1
	15. IWTYPE = 2	H-3
	16. W3 cards present	H-3
	17. BL card with preset boundary conditions	H-1
	18. BL card without preset boundary conditions	H-14

Routine	Configuration	Test
	19. BR card with preset boundary conditions	H-1
	20. BR card without preset boundary conditions	H-14
	21. Left side SS boundary condition	H-1
	22. Left side CL boundary condition	H-3
	23. Left side FR boundary condition	H-29
	24. Right side SS boundary condition	H-1
	25. Right side CL boundary condition	H-29
	26. Right side FR boundary condition	H-3
	27. Lamina thickness table	H-3
	28. Material table	H-3
	29. Angle table	H-3
	30. Flat plate	H-1
	31. Curved plate	H-3
DBLERT	See description	H-63
DC	1. LDOPT = 1	H-1
	2. LDOPT = 2	H-3
	3. LDOPT = 3	H-5
	4. LDOPT = 4	H-6
	5. LDOPT = 5	H-7
	6. LDOPT = 6	H-8
	7. LDOPT = 7	H-9
	8. Check print of merge matrix	H-20
	9. Matrix positive definite	H-20
	10. Matrix not positive definite	H-20
DTC	1. Flat plate with B = 0	H-1
	2. Flat plate with $B \neq 0$	H-2
ERROR	See description	H-75
GALUP	1. Flat plate	H-1
	2. Curved plate	H-3
	3. LDOPT = 1	H-28
	4. LDOPT = 2	H-3
	5. LDOPT = 3	H-5
	6. LDOPT = 4	H-6

Routine	Configuration	Test
	7. LDOPT = 5	H-7
	8. LDOPT = 6	H-8
	9. LDOPT = 7	H-9
INFORM	1. Flat plate	H-1
	2. Curved plate	H-3
	3. LDOPT = 1	H-1
	4. LDOPT = 2	H-2
	5. LDOPT = 3	H-5
	6. LDOPT = 4	H-6
	7. LDOPT = 5	H-7
	8. LDOPT = 6	H-8
	9. LDOPT = 7	H-9
	10. IWTYPE = 1	H-1
	11. IWTYPE = 2	H-3
	12. Edge with SS boundary condition	H-1
	13. Edge with CL boundary condition	H-3
	14. Edge with FR boundary condition	H-3
	15. Edge with input stiffness value	H-25
LOADCL	1. Upper bound input	H-1
	2. Upper bound calculated	H-3
	3. IWTYPE = 1	H-1
	4. IWTYPE = 2	H-3
	5. MSOPT = 1	H-10
	6. MSOPT = 2	H-1
LOADCN	1. First pass	H-1
	2. Second pass	H-1
	3. 0/1 crossing and determinant exponents $\leqslant 8$	H-76
	4. 0/1 crossing and determinant exponents > 8	H-10
MERGEC	See description	H-1

Routine	Configuration				Test
NEXTC	1. Illegal character				H-66
	2. Process new card				H-3
	3. Process old card				H-3
PAC	See description				Inspection
PLATEC	1.Flat plate with B = 0				H-1
	2. Flat plate with B ≠ 0				H-2
PLTDEF	1. Input by engineering constants by P2 cards				H-1
	2. Input by engineering constants by MT cards				H-3
	3. Input by matrices				H-25
	4. Angle input on same card				H-32
	5. Angle input separately				H-3
	6. Flat plate B = 0				H-1
	7. Flat plate B ≠ 0				H-2
	8. Curved plate				H-3
PLTCLC	1. Flat plate B = 0, 1, 6 and 2, 6 zero	AN11 = 0	AN12 = 0	AN22 ≠ 0	H-17
	2.	= 0	≠ 0	= 0	H-10
	3.	≠ 0	= 0	= 0	H-16
	4.	≠ 0	≠ 0	= 0	H-11
	5.	= 0	≠ 0	≠ 0	H-12
	6.	≠ 0	= 0	≠ 0	H-1
	7.	≠ 0	≠ 0	≠ 0	H-6
	8. Flat plate B ≠ 0	= 0	= 0	≠ 0	H-77
	9.	= 0	≠ 0	= 0	H-78
	10.	≠ 0	= 0	= 0	H-79
	11.	≠ 0	≠ 0	= 0	H-80
	12.	= 0	≠ 0	≠ 0	H-81
	13.	≠ 0	= 0	≠ 0	H-2
	14.	≠ 0	≠ 0	≠ 0	H-82
	15. Curved plate B = 0	= 0	= 0	≠ 0	H-21
	16.	= 0	≠ 0	= 0	H-13
	17.	≠ 0	= 0	= 0	H-20
	18.	≠ 0	≠ 0	= 0	H-15

Routine	Configuration				Test
	19. Curved plate B = 0	AN11 $= 0$	AN12 $\neq 0$	AN22 $\neq 0$	H-23
	20.	$\neq 0$	$= 0$	$\neq 0$	H-22
	21.	$\neq 0$	$\neq 0$	$\neq 0$	H-24
	22. Curved plate B $\neq 0$	$= 0$	$= 0$	$\neq 0$	H-18
	23.	$= 0$	$\neq 0$	$= 0$	H-14
	24.	$\neq 0$	$= 0$	$= 0$	H-19
	25.	$\neq 0$	$\neq 0$	$= 0$	H-25
	26.	$= 0$	$\neq 0$	$\neq 0$	H-26
	27.	$\neq 0$	$= 0$	$\neq 0$	H-4
	28.	$\neq 0$	$\neq 0$	$\neq 0$	H-27
	29. Curved plate B $\neq 0$, 1, 6 and 2, 6 terms nonzero				H-5
	30. Flat plate B = 0, 1, 6 and 2, 6 terms nonzero				H-3
PRERD	1. No end card				H-34
	2. C1 card present				H-1
	3. C2 card present				H-1
	4. C3 card present				H-1
	5. LC card present				H-1
	6. W1 card present				H-1
	7. W2 card present				H-11
	8. W3 card present				H-3
	9. BL card present				H-1
	10. BR card present				H-1
	11. TT card present				H-3
	12. MT card present				H-3
	13. AT card present				H-3
	14. P1 card present				H-1
	15. P2 card present				H-1
	16. P3 card present				H-3
	17. PA card present				H-25
	18. PB card present				H-25
	19. PD card present				H-25
	20. END card present				H-1
PRINTC	See description				H-20

Routine	Configuration	Test
RDTBLE	1. Two or more cards used	H-36
	2. E format data	H-3
	3. E format data with 14 significant digits	H-36
	4. F format data	H-3
	5. F format data with 14 significant digits	H-36
	6. Error exits	
	(a) Missing slash	H-37
	(b) Illegal data (bad character or too many characters)	H-38
	(c) Table size limit exceeded	H-39
	(d) No data found	H-65
REDUC3	1. Successful operation	H-3
	2. Unsuccessful operation	H-41
RGENER	Same as for PLTCLC	Same as PLTCLC
SELECT	1. Wave search option	H-3
	2. Non-wave search option	H-1
	3. Upper bound only	H-28
	4. Upper bound input	H-1
	5. Full solution	H-1
SOLVEC	See description	H-1
STOREC	See description	H-1
STRAIN	1. LDOPT = 1	H-1
	2. LDOPT = 2	H-3
	3. LDOPT = 3	H-5
	4. LDOPT = 4	H-6
	5. LDOPT = 5	H-7
	6. LDOPT = 6	H-8
	7. LDOPT = 7	H-9
STRMOV	See description	Inspection
SO352A	1. Full solution	H-1
	2. Upper Bound only	H-28

2.4 FUNCTIONAL TEST DESCRIPTIONS

Test	Characteristics
H-1	1. Flat plate, matrix B = 0 2. C1 title card used 3. Load option = 1, input $\overline{N}_y$ 4. BL = BR = SS 5. Input upper bound 6. Wave number option 7. MSOPT = 2 8. Input engineering constants 9. END card included
H-2	1. Flat plate, matrix B $\neq$ 0 2. Load option = 2, input $\overline{N}_x$
H-3	1. Curved plate with matrix B = 0 2. Load option = 2 3. BL = clamped 4. BR = free 5. Upper bound defaulted 6. TT, MT and AT tables used 7. Minimum wave search option used—MSOPT = 5 8. Half wave length option 9. C2 and C3 cards not present
H-4	1. Curved plate, matrix B $\neq$ 0; B_{16} and B_{26} = 0 2. Load option = 2, input $\overline{N}_x$
H-5	1. Curved plate, matrix B $\neq$ 0, B_{16} and $B_{26} \neq 0$ 2. Load option = 3 3. MSOPT = 4
H-6	1. Flat plate, matrix B = 0 2. Load option = 4, input $\overline{N}_x$ and $\overline{N}_y/\overline{N}_{xy}$
H-7	1. Flat plate, matrix B = 0 2. Load option = 5, input $\overline{N}_y$ and $\overline{N}_x/\overline{N}_{xy}$

Routine	Configuration	Test
TBPOINT	1. Repeat option left of slash	H-3
	2. Repeat option right of slash	H-3
UNPAC	See description	Inspection
VIPDR	See description	H-1
WAVFND	1. Load value for initial middle wave value is lowest of the three	H-70
	2. Load values corresponding to initial three wave values are increasing	H-71
	3. Load values corresponding to initial three wave values are decreasing	H-72
	4. Load value for initial middle wave value is highest of the three	H-73
ZARK2	See description	H-1

Test	Characteristics
H-8	1. Flat plate, matrix B = 0 2. Load option = 6, input $\overline{N}_x/\overline{N}_y$
H-9	1. Flat plate, matrix B = 0 2. Load option = 7, input $\overline{N}_x/\overline{N}_y$ and $\overline{N}_y/\overline{N}_{xy}$
H-10	1. Flat plate, matrix B = 0 2. Load option = 3 3. MSOPT = 1 for wave number loop control 4. Buckling iterations not defaulted
H-11	1. Flat plate, matrix B = 0 2. Load option = 3, input $\overline{N}_x$ 3. MSOPT = 3 4. W2 card used
H-12	1. Flat plate, matrix B = 0 2. Load option = 2, input $\overline{N}_x$ 3. Spring constants used for boundary
H-13	1. Curved plate, matrix B = 0 2. Load option = 3
H-14	1. Curved plate, matrix B $\neq$ 0 2. Load case = 3
H-15	1. Curved plate, matrix B = 0 2. Load case = 3, input $\overline{N}_x$
H-16	1. Flat square plate, matrix B = 0 2. Load option = 1
H-17	1. Flat plate, matrix B = 0 2. Load option = 2
H-18	1. Curved plate, matrix B $\neq$ 0 2. Load option = 2

Test	Characteristics
H-19	1. Curved plate, matrix B $\neq 0$ 2. Load option = 1
H-20	1. Curved plate, matrix B = 0 2. Load option = 1 3. Intermediate check print
H-21	1. Curved plate, matrix B = 0 2. Load option = 2
H-22	1. Curved plate, matrix B = 0 2. Load option = 1, input $\overline{N}_y$
H-23	1. Curved plate, matrix B = 0 2. Load option = 3, input $\overline{N}_y$
H-24	1. Curved plate, matrix B = 0 2. Load option = 7, input $\overline{N}_x/\overline{N}_y$ and $\overline{N}_y/\overline{N}_{xy}$
H-25	1. Curved plate, matrix B $\neq 0$ 2. Load option = 5, input $\overline{N}_x/\overline{N}_{xy}$ 3. Input A, B and D matrices
H-26	1. Curved plate, matrix B $\neq 0$ 2. Load option = 4, input $\overline{N}_y/\overline{N}_{xy}$
H-27	1. Curved plate, matrix B $\neq 0$ 2. Load option = 7, input $\overline{N}_x/\overline{N}_y$ and $\overline{N}_y/\overline{N}_{xy}$
H-28	1. Same plate as H-1 2. Calculate upper bound only
H-29	1. BL = free 2. BR = clamped
H-30	1. Boundaries restrained

Test	Characteristics
H-31	1. Free boundaries
H-32	1. Fiber angle input by P2 card
H-33	1. C1 card not present
H-34	1. No END card
H-35	1. Illegal character in P3 card
H-36	1. Two cards used for W3 card
H-37	1. Slash missing in W3 card
H-38	1. Illegal character in W3 card
H-39	1. W3 card table size limit exceeded
H-40	1. No data found on W3 card
H-41	1. Size load greater than critical load, plate already buckled
H-42	1. Stack of H3 data sets 2. LC card missing in first set 3. W1 card missing in 2nd set 4. W3 card missing in 3rd set 5. BL card missing in 4th set 6. BR card missing in 5th set 7. TT card missing in 6th set 8. MT card missing in 7th set 9. AT card missing in 8th set 10. P1 card missing in 9th set 11. P3 card missing in 10th set
H-43	1. H-2 except JPC(3) = -10 on C3 card

Test	Characteristics
H-44	1. H-2 except load option = 8
H-45	1. H-3 except 41 material tables input
H-46	1. H-3 except plate type = 0
H-47	1. H-3 except material property option = 2
H-48	1. H-3 except material properties input format option = 2
H-49	1. Problem with 26 layers
H-50	1. H-3 except wave option = 1 used with initial half-wave length value higher than second and a negative delta supplied 2. Half-wavelength list exceeds 30 values
H-51	1. H-3 except BL = BL
H-52	1. H-3 except wave-value definition on the W1 card is left blank
H-53	1. H-3 except wave value definition is set equal to 1
H-54	1. H-3 except for the following items: 2. MT table has 3 values 3. Radius is set negative 4. Length value is given
H-55	1. Insufficient P2 cards
H-56	1. Invalid table number
H-57	1. An input E_{22} value is zero
H-58	1. An input E_{11} value is zero

Test	Characteristics
H-59	1. Data set containing a card which is an invalid type
H-60	1. Data set with P2 and P3 cards
H-61	1. Data set with a missing P3 card
H-62	1. An end-of record card following an MT card
H-63	1. Double root occurs
H-64	1. An MT card starts list with a comma
H-65	1. W3 card with a slash only
H-66	1. Illegal character on a P3 card
H-67	1. P3 card starts with 2 commas
H-68	1. Unequal number of commas in P3 sublists
H-69	1. Upper bound input as too low 2. Critical wave search option chosen
H-70	1. Critical wave search option is input 2. Wave-load configuration 1 (see subroutine description)
H-71	1. Critical wave search option is input 2. Wave-load configuration 2 (see subroutine description)
H-72	1. Critical wave search option is input 2. Wave-load configuration 3 (see subroutine description)

Test	Characteristics
H-73	1. Critical wave search option is input 2. Wave-load configuration 4 (see subroutine description)
H-74	1. α roots of each type—pure real, pure imaginary, and complex—occur. (This is not an input data set; subroutine ZARK2 altered for the test.)
H-75	1. Error exit through subroutine ERROR occurs
H-76	1. Test of LOADCN with determinant exponents $\leqslant 8$
H-77	1. B $\neq 0$ 2. N11 = 0 and N12 = 0 3. N22 = variable
H-78	1. B $\neq 0$ 2. N11 = 0 and N22 = 0 3. N12 = variable
H-79	1. B $\neq 0$ 2. N12 = 0 and N22 = 0 3. N11 = variable
H-80	1. B $\neq 0$ 2. N12 = 1000.0 and N22 = 0 3. N11 = variable
H-81	1. B $\neq 0$ 2. N11 = 0 and N12 = 1000.0 3. N22 = variable
H-82	1. B $\neq 0$ 2. N11 = 1000.0 and N12 = 60.0 3. N22 = variable
H-83	LT, LA, LM cards are used in data input.

ENGINEERING VARIABLE GLOSSARY

This shows the correspondence between the engineering variables in the analysis document, reference 1, and the program variables.

Engineering variable	Description	Program variable
a	*length of the plate*	PLONG
A_{ij}	extensional stiffnesses (i, j = 1, 2, 6), equation (A-6)	A
A^*	matrix for strain calculation, equation (A-56)	AST
b	developed width of the plate	WIDE
B_{ij}	stiffnesses (i, j = 1, 2, 6) associated with bending-stretching coupling, equation (A-6)	B
D_{ij}	bending stiffnesses (i, j = 1, 2, 6), equation (A-7)	D
E_{11}, E_{22}	Young's moduli of orthotropic lamina	E1, E2
G_{12}	shear modulus of orthotropic lamina	G12
h_k	distance to k^{th} lamina from the reference plane	H(K)
k_w, k_θ, k_v, k_u	spring constants	DSTIFF
ℓ_1, ℓ_2	direction cosines	X, Y
$\overline{L}_{1j}, \overline{L}_{2j}$	displacement ratio coefficients, equations (A-38) and (A-39)	L1, L2
$\hat{M}$	moment resultant, equation (A-15) and (A-19)	CZ
n	number of laminas	LAYERS
N_x, N_y, N_{xy}	stress resultants, equation (A-6)	STR

Engineering variable	Description	Program variable
$\overline{N}_x, \overline{N}_y, \overline{N}_{xy}$	applied inplane loads	AN11, AN12, AN22
p_j	buckling displacement parameter	p
Q_{ij}	orthotropic material constants (i, j = 1, 2, 6) with respect to material axes, equation (A-5)	Q11, Q12, Q22, Q33
$\overline{Q}_{ij}$	orthotropic material constants (i, j = 1, 2, 6) with respect to plate axes, equation (A-3)	Q
$\hat{Q}$	effective transverse shear, equations (A-14) and (A-18)	CW
R	reference plane radius of curved plate	RADIUS
$R_{11}, R_{12}, \ldots R_{33}$	elements of coefficient matrix R, equation (A-37)	R
s	stiffness matrix for the plate, equation (A-53)	ST
S	modified merged stiffness matrix, equation (A-54)	DBMA
t_k	thickness of k^{th} layer of the laminate	TH(K)
t	laminate thickness	TOT
$\hat{T}$	effective inplane shear, equations (A-17) and (A-20)	CU
X_d, X_f	displacement and force matrices, respectively, equations (A-45) and (A-51)	XD, XF
α_j, β	buckling displacement parameters, equations (A-34) through (A-36)	ALPHA, BETA
γ_{xy}	shear strain	STR(3)
ϵ_x, ϵ_y	normal strains	STR(1), STR(2)

Engineering variable	Description	Program variable
λ	half-wavelength of buckling in the x-direction	SWAVE
ν_{12}, ν_{21}	Poisson's ratio	RNUA, RNUB
ϕ_k	angle defining orthotropy directions of k^{th} lamina, with respect to plate axes	ANGLE

Subscripts

j	index corresponding to characteristic roots	
k	layer index	

A subscript preceded by a comma indicates partial differentiation with respect to the subscript.

Superscripts

T	matrix transpose	
o	quantities in the reference plane of the plate	
+	quantities along the side $y = +\frac{b}{2}$ of the plate	
	quantities along the side $y = -\frac{b}{2}$ of the plate	

REFERENCES

1. Viswanathan, A. V.; Tamekuni, M.; and Baker, L. L.: Elastic Stability of Laminated, Flat and Curved, Long Rectangular Plates Subjected to Combined Inplane Loads. NASA CR-2330, 1973.

2. Halstead, David, W.; Tripp, L. L.; Tamekuni, M.: and Baker, L.L.; BUCLAP2—A Computer Program for Instability Analysis of Laminated Long Plates Subjected to Combined Inplane Loads—User's Manual. NASA CR-132298, 1973.